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Method for Obtaining a Picture of the Internal Structure of an Object Using X-Ray Radiation and Device for the Implementation Thereof

The suggested inventions relate to the means of intraviewing and are meant for image formation of the internal structure of the object, in particular biological, with the use of X-rays. These inventions are supposed to be used in the defectoscopy and medicine diagnostics.

The varied methods and devices of the said purpose, realizing the traditional principles of projection roentgenoscopy, are known. Such methods and devices are used to get an image formation of the internal structure of the object, for instance the tissues of biological objects, as a shady projection. The density of the resulting image in each of its point is defined by summary reduction of X-rays, passed through the object under study from the source to the facilities of detection. As the last said are a fluorescent screen or X-ray film, which should be chemically treated to get the image visualization (see Polytechnical Dictionary. Moscow, “Soviet Encyclopedia”, 1976 [1], p. 425; Physics of image visualization in medicine. Edited by S. Webb. Moscow, “Mir”, 1991 [2], p. 40-41).

The image of real three-dimensional structure in the said two-dimensional shady projection form is gained in above said methods and devices. The specialist, analyzing the object (in particular, in technical and medicine diagnostics), must have proper qualification and experience, because sometimes he can meet difficulties in the interpretation of the said projection. The reasons for it are: low contrast, moderate signal-noise relation, unfailingly laying down of the structure elements image, impossibility of quantitative comparison of separate

local fragments of the object by density. The image sharpness and contrast range decrease as well under the effect of quanta, hitting on the detection facilities of secondary Compton scattered radiation.

Methods and devices for X-ray computer tomography for obtaining two-dimensional image of thin layer of three-dimensional object are known as well (V.V. Piklov, N.G. Preobrazhenskiy. Computational tomography and physical experiment. The progress of physical sciences, v. 141, 3rd ed., November 1983, p. 469-498 [3]; see also [2], p. 138-146). The multiple irradiation of the object under study from different points and reception of the radiation, passed through this object, by the detectors ruler are effected in such methods and devices. The distribution of densities of the object tissues in the cross-section under study is obtained in the discrete form by solution to the system of equations with the use of computer (the order of the form and the quantity of the resolution elements correspond the product of the positions quantity, from which the irradiation is realized, by the quantity of the detectors). Three-dimensional object image can be obtained on the basis of two-dimensional lit-parlit images set by irradiation in different cross-sections. High quality of the image can be obtained with the use of computed tomography, and this image presents the picture of distribution of tissues density (not the picture caused by integral absorption of substance (for instance biological tissues) placed on the radiation way from the source to one or other element of visible projection). However it can be obtained by increasing of quantity of positions of irradiation. In this case the radiation dose absorbed by the substance increases, what is undesirable (it's often prohibitively in medical applications). The presence of the scattered Compton radiation is a negative factor, effecting on this group of known methods and devices too. Medical applications of methods and devices of both examined groups are characterized by intensive irradiation, acting on

tissues and organs of no interest for investigation, when they are on the radiation way (before and after the area under study). The irradiation in methods and devices of the second group is less than in the first one owing to the choice of different positions when different tissues and organs, surrounding those under study, are under irradiation.

The increase of resolution in the means of the second group, demanding the enlargement of quantity of irradiation from different points, is limited, first of all, by prohibilitively increasing of the irradiation dose. The technical facilities for the primary information production and subsequent reconstruction of the image are very complicated. It is conditioned both by the necessity of usage of fast computers with special software and high demands to the accuracy of mechanical elements of the construction. These elements should guarantee the right localization of the same elements of resolution of the area under study when irradiating them from the different points. The latest depends on actual data (deduced in different cycles of irradiation, but referred to the same elements of resolution), which should figure in the calculations when reconstructing the image.

Methods and devices of the second of said group (the information in discrete form about the density of each element of resolution is gained in them) are very close to assumed ones.

The proposed investigations are purposed to get the following technical result: the rise of the accuracy of defining of the relative indexes of the substance density of the obtained image in combination with the refusal from the complicated and expensive technical means. The usage of the proposed investigations in medicine diagnostics and other researches, connected with the influence on biological substances, allows to decrease the irradiation dose on the tissues, surrounding that ones under study.

To obtain the said kinds of the technical result of the proposed method of the image formation of the internal structure of the object with the use of X-rays, this radiation should be concentrated in the zone with the point, the current results of measurements are referred to. Secondary radiation (Compton scattered coherent and incoherent, fluorescence radiation), resulting from this zone, is transported to one or more detectors. The scanning of the object's zone under study is realized by moving the said zone. Simultaneously the coordinates of the zone of X-rays concentration with the point, the current results of measurements are referred to, are defined and fixed. The density of the object substance in the said point results from the values of secondary radiation intensity, obtained from one or more detectors and defined at the same time with the coordinates of this point. The obtained values, taken as the indexes of density of the object substance, with the coordinate values, corresponding to them, are used for modeling the picture of distribution of substance density of the object area under study. Moving the zone of X-rays concentration for scanning the area under study is realized by the relative shift of the object under study and mutual displacement of static with respect to each other X-ray sources, means for X-rays concentration; means for transportation the secondary radiation toward the detectors, and the detectors themselves.

Common for known ([2], p. 138-146, [3], p. 471-472) and proposed methods is X-rays action on the object under study, when the relative shift of the object under study and X-ray optical system, which includes X-ray sources together with their control means and detectors, is realized.

The proposed method differs from others in the presence of the operation of X-rays concentration in the zone with the point, the current results of measurements are referred to. The scanning is a common feature for known and proposed methods, but it's realized completely

differently in the last one, namely by moving the current position of X-rays concentration zone to the vicinity of the next point, for which the substance density of the object under study is being defined. The transportation of the secondary radiation (scattered Compton coherent and incoherent, fluorescent radiation), excited in the concentration zone, from this zone to the detector (detectors) is the distinctive feature too.

In this case the said secondary radiation acts on the detector (detectors), but not the source radiation passed through the subject under study. As is well aware, the intensity of the secondary radiation, with other things being equal (see J. Jackson. Classical Electrodynamics. M., "Mir", 1965, pp. 537-538 [4]), is proportional to the density of the substance, in which this radiation is excited, irrespective of substance nature. Owing to this fact the secondary scattered radiation, being preventing factor in the known method, becomes the information factor. The usage of the current values of the secondary radiation density as a substance density coefficient in the point, the current results of measurements are referred to, is the difference of the proposed method as well.

The differences of the proposed method from the known one are characterized below in the description of the possible specific cases of the realization of this method. These cases allow using the different combinations of methods for X-rays concentration and the secondary scattered radiation transporting.

In the specific case one or more collimators are used to concentrate X-rays in the zone with the point, the current results of measurements are referred to. In this case the proper quantity of spaced X-ray sources is used. The formatted secondary radiation is transported to one or more detectors by one or more collimators, as well. In this case all collimators

are oriented to cross the axis of their central channels in the point, the current results of measurements are referred to.

In the other specific case the X-rays concentration in the zone with the point, the current results of measurements are referred to, is obtained by using one or more X-ray half-lenses, which transform the divergent radiation of the proper quantity of spaced X-ray sources to quasi-parallel. In this case one or more X-ray half-lenses or lenses, focusing this radiation on the detectors, allow transporting the formatted secondary radiation to one or more detectors. The transportation of the secondary radiation to one or more detectors by means of one or more X-ray half-lenses, forming quasi-parallel radiation, is also possible. In this case all X-ray lenses and half-lenses should be oriented to cross their optic axis in the point, the current results of measurements are referred to.

In one more specific case X-rays concentration in the zone with the point, the current results of measurements are referred to, is realized by one or more X-ray half-lenses, which transform the divergent radiation of the proper quantity of the spaced sources into quasi-parallel. The formatted secondary radiation transporting to one or more detectors is realized by one or more collimators. In this case X-ray half-lenses and collimators should be oriented to cross all optic axis of all X-ray half-lenses and the central channels of all collimators in the point, the current results of measurements are referred to.

The X-rays concentration in the zone with the point, the current results of measurements are referred to, is also realized by the usage of one or more spaced X-ray sources and the proper quantity of X-ray lenses. These lenses focus the divergent X-rays of each source in the point, the current results of measurements are referred to. The formatted secondary radiation transporting to one or more detectors is realized by X-ray

lenses, which focus this radiation on the detectors and possess the second focus in the said point.

In the specific case, providing for X-rays concentration in the zone with the point, the current results of measurements are referred to, with the usage of one or more spaced X-ray sources and the proper quantity of X-ray lenses, focusing the divergent roentgen radiation of each source in the fixed point, the transportation of the formatted secondary radiation to one or more detectors can be realized with the usage of collimators, which are oriented to cross the optic axis of their central channels in the same point.

The suggested device for the image formation of the internal structure of the object with the use of X-rays contains: means for the object under study positioning, X-ray optic system, means for relative moving of the means for the object under study positioning and X-ray optic system, means for the data processing and image, the detectors for the determination of the point's coordinates. The point is positioned in the object's substance under study and the measurement results are referred to it. The results are related to the means for the object under study positioning and X-ray optic system, which are connected with the means for the data processing and image with their outputs. Thus X-ray optic system consists of: one or more X-ray sources, means for the radiation concentrating of said one or more X-ray sources in the zone with the point, the current results of measurements are referred to, one or more means for the formatted secondary radiation transporting, and the radiation detectors, positioned at the means outputs. The detectors outputs are connected with the means for the data processing and image.

Common for known and suggested devices is the presence of the means for the object under study positioning, X-ray optic system, the

means for moving them relative to each other, the coordinate detectors, as well as the means for the data processing and image.

Unlike the known device, X-ray optic system of the suggested one contains the means for the radiation concentrating of the said one or more X-ray sources in the zone with the point, the current results of measurements are referred to. Besides, this system contains one or more means for the formatted secondary radiation transporting to the detectors of this radiation, owing to this fact precisely this radiation (and not the radiation of the source (sources), passed through the subject under study) falls at the detectors inputs. The coordinate detectors carry another function in the suggested device than in the known one: they determinate the coordinates of the point, the current results of measurements are referred to. The function of the means for the data processing and image is different as well: this means manipulates with the input data, directly carrying the information about the substance density and the coordinates of the point, to which these data are referred. The construction of the proposed device and the principle of its function create prerequisites for the total elimination of accuracy and resolution dependence on the means for the data processing, as these indexes of the device quality are practically entirely defined by used parameters of the means for X-rays concentration.

Other differences, peculiar to the suggested device in different specific cases of its carrying out, are characterized below.

In one of these specific cases X-ray system of the suggested device contains several X-ray sources. Thus every means for the radiation concentration of the sources in the zone with the point, the current results of measurements are referred to, and every means for the formatted secondary radiation transporting to the detectors, are made as the collimator with the channels, oriented to the zone of radiation

concentrating of X-ray sources. The optic axes of the central channels of all collimators cross in the point, the current results of measurements are referred to.

In this specific case X-ray sources of X-ray optic system may be quasi-point. Thus the collimators have the channels, focused on these sources, and diverging (widening) toward the means for the positioning of the object under study. The screen with the aperture is located between the output of each X-ray source and the input of corresponding collimator.

In the same specific case X-ray sources of X-ray system may be extended. Thus the collimators have the channels, converging (narrowing) toward the means for the positioning of the object under study.

In the other specific case of carrying out of the suggested device, X-ray sources of X-ray system are quasi-point. Each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray half-lens, transforming the divergent radiation of the corresponding source to quasi-parallel. Each means for the formatted Compton secondary radiation transporting toward the detector is made as X-ray half-lens, focusing this radiation on the detector. Thus the optic axes of all X-ray half-lenses cross in the point, the current results of measurements are referred to.

In the following specific case of realizing the suggested device, as in the previous one, X-ray sources of X-ray system are quasi-point. And each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray half-lens, transforming the divergent radiation of the corresponding source to quasi-parallel. However, in distinction to the previous case, an each means for the formatted secondary radiation transporting to the detector is

made as X-ray half-lens. A lens focus is in the point, the current results of measurements are referred to, and a lens transforms the said radiation to quasi-parallel and directs it at the detector. Thus optic axes of all X-ray half-lenses cross in the point, the current results of measurements are referred to.

In one more specific case X-ray sources of X-ray optic system are quasi-point too, each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray half-lens, which transforms the divergent radiation of the corresponding source to quasi-parallel. However, in contrast to the previous case, each means for the formatted secondary radiation transporting to the detector is made as X-ray lens, focusing this radiation on the detector and having the second focus in the zone of X-rays concentration. The optic axis of all X-ray half-lenses and lenses cross in the point, the current results of measurements are referred to.

In the following specific case, as in previous two, X-ray sources of X-ray optic system are quasi-point and each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray half-lens, which transforms the divergent radiation of the corresponding source to quasi-parallel. As this takes place each means for the formatted secondary radiation transporting to the detectors is made as collimator with the channels, diverging (widening) toward the corresponding detector. The optic axes of all X-ray half-lenses and the central channels of the collimators cross in the point, the current results of measurements are referred to.

X-ray optic system of the suggested device can be made as following. X-ray sources of this system are quasi-point. Each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray half-lens, transforming

the divergent radiation of the corresponding X-ray source to quasi-parallel. Each means for the formatted secondary radiation transporting to the detector is made as the collimator with the channels, converging (narrowing) toward the corresponding detectors. The optic axes of all X-ray half-lenses and the central channels of the collimators cross in the point, the current results of measurements are referred to.

The next specific case of carrying out the suggested device is characterized by the following: X-ray sources of X-ray optic system are quasi-point; each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray half-lens, focusing the divergent radiation of X-ray source; each means for the formatted secondary radiation transporting toward the detector is made as the collimator with the channels, narrowing (converging) toward the corresponding detector. Thus the optic axes of all X-ray lenses and the central channels of the collimators cross in the point, the current results of measurements are referred to.

One more specific case of carrying out the device is characterized by the following: X-ray sources of X-ray optic system are quasi-point; each means for X-rays concentration in the zone with the point, the current results of measurements are referred to, is made as X-ray lens, focusing the divergent radiation of X-ray source; each means for the formatted Compton secondary radiation transporting towards the detector is made as the collimator with the channels, widening (diverging) towards the corresponding detector. Thus the optic axes of all X-ray lenses and the central channels of the collimators cross in the point, the current results of measurements are referred to.

The suggested inventions are illustrated by drawings, including:

fig. 1, depicts the basic principals of the suggested device: the schematic image of mutual location and joint of the main elements for carrying out the suggested device;

fig. 2 & 3 depict special cases of the method realization and carrying out the device with the use of collimators for X-rays concentration and the secondary radiation transporting toward the detectors;

fig. 4 & 5 depict the same with the use of X-ray half-lenses;

fig. 6 depict the same with the use of X-ray half-lenses for X-rays concentration and "full" X-ray lenses for the secondary radiation transporting toward the detectors;

fig. 7 & 8 depict the same with the use of X-ray half-lenses for X-rays concentration and the collimators for the secondary radiation transporting toward the detectors;

fig. 9 depicts the same with the use of X-ray lenses for X-rays concentration and the secondary radiation transporting toward the detectors;

fig. 10 & 11 depict the same with the use of X-ray lenses for X-rays concentration and the collimators for of the secondary radiation transporting towards the detectors.

The suggested method is effected by means of the suggested device as follows:

Divergent X-rays from the quasi-point source 1 (fig. 1) is focused by X-ray lens 2 in the predetermined point 4 of the area under study 7 of the object (for instance, biological). This object is positioned as required by means of the means 10 for positioning. The radiation, focused in the point 4, excites the secondary divergent radiation of the object substance 5 (coherent and incoherent Compton radiation, fluorescence radiation). The intensity of the secondary radiation within fluctuations, caused by the stochastic character of the process of exciting of the secondary radiation,

is proportional to the density of the substance, which the radiation appears from. The focus of the second X-ray lens 3 is in the same point. This lens captures and then focuses the scattered secondary radiation on the detector 6, which transforms it to electrical signal, conducted to the means 12 input for data processing and image 12. The choice of the position for the total focus point 4 of the lenses 1 and 3 is realized by moving with respect to each other the means 10 for the object positioning and the group of the device elements (X-ray optic system 8 with X-ray source 1, X-ray lenses 2, 3 and the detector 6 of radiation).

It should be explained that the lenses for X-rays control (the divergent radiation focusing, the quasi-parallel beam forming from the divergent radiation, the quasi-parallel beam focusing, etc.) present the combination of curved channels for the radiation transporting. The radiation in these channels is exposed to multiple total external reflections (see, for instance: Arkadiev V.A., Kolomiytsev A.I., Kumakhov M.A. et al. Broadband X-ray optic with wide angular aperture. The Progress of Physics, 1989, vol. 157, issue 3, p. 529-537 [6], where the first lens of this type is described; USA patent No. 5744813 (published 28.04.98) [7], where the modern lens is described). A lens as a whole is barrel-shaped (i.e. it is narrowing toward both faces), if the lens is meant for the divergent radiation focusing, or it is half barrel-shaped (i.e. only one face is narrower), if it is meant for the divergent radiation to quasi-parallel transforming, or for said radiation focusing. The terms “full lens” and “half-lens” are widely used to determinate the lenses of two said types.

Fig. 1 depicts two possible variants of the device operation and usage. In one variant the means 10 for the object under study positioning, with the object under study 5 placed in it, is static. And X-ray system displaces (fig. 1, arrows 9 show the possibility of X-ray system displacement), keeping the mutual arrangement of the elements 1, 2, 3 and 6

(consequently coinciding of the focuses of the lenses 1 and 3). In the other variant, visa versa, X-ray system 8 is static, and the means 10 for positioning together with the object under study 5 displace. The utility of realization of one variant or another depends on the object 5 sizes and mass as compared with sizes and mass of the group of the above-listed elements, comprising X-ray system 8.

The means contains as well the coordinate detector 11, reacting to relative motion of X-ray optic system 8, and the means 10 for positioning, which is connected with the detector 11. The detector 11 must be adjusted to form the signals, proportional to the current coordinates of the common focus point 4 of the lenses 2 and 3, regarding the chosen origin reading, which is connected with the means 10 for positioning. The output signals of the detector 11, as well as the output signal of the detector 6, are supplied to the inputs of the means 12 for data processing and image. In this case the focus point 4 is the point, the current results of measurements are referred to; the radiation of the source 1 is concentrated, in fact, in the surroundings of this point, considering the finite dimension of the focus zone of X-ray lens 2. The means 12 for data processing and image provides the image reconstruction of density distribution, realizing one or other formation algorithm of two- or three-dimensional image on the screen (see, for instance, E. Lapshin. Graphics for IBM PC. M., "Solon", 1995 [5]). In the simplest case, when, for instance, scanning (the displacement of X-rays concentration zone with the point 4, the current results of measurements are referred to) is realized on some plane section of the object 5, image scan of the means 12 with long afterglow on the screen can be performed simultaneously. The storing of the definite number of the measurement results with the succeeding periodical image scan is possible as well, etc.

The principal of operation of suggested inventions is based on the fact that the density of the scattered secondary Compton radiation (the probability of quanta formation of this radiation) is proportional to the substance density, all other factors being equal (in particular, at given primary X-rays intensity, acting on the substance).

As it was said in the description of the suggested method and device essence, the main feature of these inventions is the use of quanta of the scattered secondary Compton radiation as informants, as distinct from the known methods and devices, in which the quanta have harmful effect.

As it was said, when the suggested inventions are used in medicine, the possibility of production of the reasonable accuracy, when the irradiation doses of biological tissues decrease, is the important advantange.

To estimate the possible gain let's take the following suppositions: the photons energy is $E=50\ keV$; X-rays concentration zone is at the 50 mm depth and has dimensions $1mm \times 1mm \times 1mm$ (these values are, for instance, characteristic for the observing conditions and precise work in the mammography researches); the detector senses 5% of the secondary radiation, originating at $5\ cm$ depth (this supposition means that the secondary radiation covers a distance of 5 cm in the patient's body, before this radiation falls on the input of the means for the radiation transporting to the detector, thus the capture angle of the lens or collimator, delivering the secondary radiation to the detector, is $0,05 \times 4\pi$ steradian). Taking into account that the linear photon absorption factor in the patient's body is close to such in the water, at the energy of $E=50\ kev$ it is of the order of $2 \times 10^{-1}\ 1/cm$, so we get the following: the intensity of the primary radiation beam, penetrating at the depth of 5 cm, decreases in $exp(2 \times 10^{-1} \times 5) = e \approx 2,71$ times. The intensity of the secondary radiation (its photon energy is close to $50\ keV$) decreases, as well, in $e \approx$

2,71 times, emerging from the patient's body. Thus, the total intensity loss as a result of the radiation absorption in the patient's body is $e \times e \approx 7{,}3$ times. Let's take into consideration only Compton component of the secondary radiation, underrating the estimated gain. The probability of formation of quanta of the Compton secondary radiation at the thickness σ_k is $\varphi = \sigma_k \times N_e \times \Delta\chi$, where the section of the secondary Compton scattering is $\sigma_k = 6.55 \times 10^{-25}\ cm^2$; the electrons density in the water is $N_e = 3 \times 10^{23}\ 1/cm^3$. Thus, at $\Delta\chi = 1\ mm = 10^{-1}\ cm$ the probability of $\varphi = 6.55 \times 10^{-25} \times 3 \times 10^{23} \times 10^{-1} \approx 2 \times 10^{-2}$. In other words, in average, $1 : (2 \times 10^{-2}) = 50$ photons of the primary radiation are necessary to form one secondary photon on the length $\Delta\chi = 1\ mm$.

Let's require that the error of the density estimate (i.e. the quantity of secondary photons dating) should be of *1%* order. With consideration of the probable process character the mean square value of the relative error is $\sigma = 1/(N)^{1/2}$, where N is the quantity of the registered photons. $N = 10000$ corresponds to the value $\sigma = 0{,}01$.

Now it's possible to set up a simple equation for N_x – the necessary quantity of primary photons, penetrating *5 cm* depth and forming there the secondary Compton radiation. It penetrates, in its turn, *5 cm* depth, and in this case $N = 10000$ photons fall on the detector:

$$N_x \times e^{-2} \times 5 \times 10^{-2} \times 2 \times 10^{-2} = 10^4.$$

Here the coefficient 5×10^{-2} means that only $5\% = 5 \times 10^{-2}$ photons fall on the detector and are registered of the total quantity of the formed secondary photons. The equation gives $N_x = 7{,}3 \times 10^7$.

Photons with the energy $E = 50\ keV$ form the irradiation zone equal to 1 roentgen, if the photon flux is equal to $2{,}8 \times 10^{10}\ 1/cm^2$ (tabulated data for

the relationship between the photon energy, their quantity and the doze see, for instance, in [2]). If the cross-section of the primary X-rays beam is equal to $1\ cm^2$ on the input of the patient's body, so the flux $7{,}3 \times 10^7$ $1/cm^2$ forms the irradiation zone equal $2{,}6 \times 10^{-3}$ roentgen in the patient's body.

In traditional X-rays tomography, for instance, when examining osteoporosis, the irradiation doze is usually 100 ÷ 300 milliroentgen, i.e. 100 times larger (V.I. Mazurov, E.G. Zotkin. Topical questions of osteoporosis diagnostics and treatment. Saint-Petersburg, IKF "Foliant", 1998, p. 47 [8]).

The doze can be decreased in several times if the irradiation is performed from several sources, which beams fall on the concentration zone in different ways and they don't store in the patient's body.

Therefore it's more appropriate to use that variants of carrying out the suggested method and device, in which several spaced X-ray sources and the detectors with corresponding quantity of the means for radiation concentration and the secondary Compton radiation transporting towards the detectors (lenses, half-lenses, collimators) are used. On one hand, it allows to obtain more effective radiation concentration (if the only means for concentration is used this concentration is possible only with the use of X-ray lens, as shown in fig. 1), and to increase the signal/noise relation on the detectors outputs. On the other hand, it makes possible to spread X-rays influence on the object under study, and to avoid the irradiation over doze on the object parts, which are not supposed to be studied. The use of several detectors with simple averaging (or more complicated processing of the output signals of the different detectors of the means 12 for data processing and image (for instance, "weighting" averaging), or processing, considering the presence of densities correlation in the points close to each other), all other things being equal, allows to use X-ray

sources of lesser power without the accuracy loosing. Besides, as averaging, the influence of other factors, decreasing the accuracy, falls (for instance, various absorption of the radiation by the source on the way towards the different points for the density determining, and the secondary radiation on the way from these points toward the inputs of the means for the secondary Compton radiation transporting towards the detectors).

These variants are examined below (fig. 1 – fig. 11).

The variants, shown in fig. 1 and fig. 2, are simplest for the technical realization.

In the scheme in fig. 2 quasi-pointed X-ray sources 1 and the collimators 13 with the channels, diverging (widening) toward the radiation distribution for this radiation concentrating in the zone 16, are used. The screens 14 with apertures for the radiation transmission on the collimators inputs, and preventing the radiation direct falling on the object (bypassing the collimators), are positioned between the sources 1 and the collimators 13. The secondary radiation is transported to the detectors 6 by the collimators 15 with the channels, converging (narrowing) toward the radiation propagation (i.e. toward the detectors 6). These channels can have the focus on the detectors sensitive surface. It's possible to use, as the detectors 6. for instance, the semiconductor detectors with the small entrance aperture.

In fig. 3 the collimators have the orientation, opposite the one, shown in the fig. 2. It's appropriate to use the extended X-ray sources 17 to take full advantage of the entrance aperture of the collimators 18, concentrating the radiation in the zone 16. It's the same reason to use the detectors 20 with the wide aperture (for instance, of the scintillation type).

In fig. 4 the means for the radiation concentration of the quasi-pointed sources 1 and the means for the secondary radiation transporting are made as X-ray half-lenses 21, 22 correspondingly. As this takes place the half-lenses 22 focus the scattered secondary radiation on the detectors 6.

In fig. 5 the means for the radiation concentration of the quasi-pointed sources 1 and the means for the secondary radiation transporting are made as X-ray half-lenses 21, 23 correspondingly. As this takes place the half-lenses 23 transform the scattered secondary radiation to quasi-parallel and direct it to the detectors 20 with the wide entrance aperture.

In fig. 6 the combined variant is shown: the means for the radiation concentration of the quasi-pointed sources 1 are made as X-ray half-lenses 21, directing the parallel beams to the zone 16. And the means for the secondary Compton radiation transporting to the detectors 6 are made as the "full" X-ray lenses 3.

In fig. 7 and 8 the other combinations are shown, differing from the previous one in the fact that the means for the secondary Compton radiation transporting toward the detectors are made as the collimators.

In fig. 7 the collimators 19 have the channels, widening to the detectors 6, and the last ones have the wide entrance aperture.

In fig. 8, the collimators 15, vice versa, have the channels, narrowing to the detectors 6, and the last one have the narrow entrance aperture.

In fig. 9 the most effective variant with respect to the accuracy and resolution is shown. In this variant the means for the radiation concentration of quasi-pointed sources 1 and the means for the secondary radiation transporting to the detectors 6 are made as the "full" lenses 2 and 3 correspondingly (compare this variant with the one, shown in the fig. 1).

In fig. 10 and 11 two more combined variants are shown. They are common in using the "full" X-ray lenses 2 as the means for the radiation concentration of the quasi-pointed sources 1.

In fig. 10 the use of the collimators 15, narrowing toward the detectors, is shown as the means for the secondary radiation transporting to the detectors 6 with the narrow aperture.

In fig. 11 the use of the collimators 19, widening toward the detectors, is shown as the means for the secondary Compton radiation transporting to the detectors 20 with the wide aperture.

The use one or another scheme of realization of the method and the device modeling depends on: the opportunity to use such effective means for radiation concentration and transporting (i.e. X-ray lenses and half-lenses), and the required resolution. The last factor influences on the choice of the lenses and half-lenses parameters as well (such as the size of the focal spot, the extent of the focal zone toward the lens optic axis, etc.). Thus it must be taken into account that the realization of the high resolution when using the "full" lenses (of some parts of millimeter and higher) demands more time for scanning of the subject area under study. Other circumstances must be taken into account as well, such as the availability the X-ray sources of needed capacity and size, etc.

The availability of described and many other variants of the suggested method realizing and the suggested device modeling gives various opportunities for construction of the means for intraviewing, satisfying the placed concrete requirements.

The information sources

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